UNIVERSITY OF CALIFORNIA
COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION

CIRCULAR No. 250
JULY, 1922

MEASUREMENT OF IRRIGATION WATER ON THE FARM

BY
H. A. WADSWORTH

CONTENTS

PAGE
Introduction ... 2
Units of measurement and equivalents ... 3
Weirs ... 4
Rectangular weirs ... 7
Cipolletti weirs ... 9
90-degree triangular-notch weirs ... 11
Weir construction ... 12
Submerged orifices ... 14
Submerged orifices of fixed dimensions ... 18
Construction of submerged orifices of fixed dimensions ... 20
Computations if tables are not available ... 20
Adjustable submerged orifices ... 21
Theory of inch box measurement ... 23
Riverside box ... 24
Anaheim Union Water Company measuring box ... 25
Santa Ana Valley Irrigation Company miner's inch box ... 26
Azusa hydrant ... 27
Division boxes ... 29
Mechanical devices for measuring water volumetrically ... 31
Reliance meter ... 32
Dethridge meter ... 33
Other measuring devices ... 34
Lyman meter ... 34
Sentinel meter ... 34
Venturi meter ... 34
Venturi flume ... 35
Summary ... 35

TABLES

1. Discharge table for rectangular weirs ... 8
2. Discharge table for Cipolletti weirs ... 10
3. Discharge table for triangular notch ... 12
4. Weir board dimensions ... 13
5. Dimensions for weir boxes ... 14
6. Discharge table for submerged orifices of fixed dimensions ... 19
7. Dimensions for boxes for submerged orifices of fixed dimensions ... 20

INTRODUCTION

The aim of this circular is to make available in a single publication the tables, and in some cases the formulae, necessary for the measurement of irrigation water under the varying conditions found in California. In order to avoid confusion, only those methods which are in common use have been considered in detail.

Even with this limitation, it has been necessary to include a considerable number of methods of measurement. This is due to the variation in conditions under which irrigation water is delivered. As an example, in the Orland area in the Sacramento Valley, where field ditches are built on fairly steep grades, small weirs are used almost exclusively to measure irrigation water to the water user. In other areas where canal grades are much flatter and where the head of water in the canal is subject to wide fluctuations, the submerged orifice is used as a measuring device. In general these orifices are so built that the size of the orifice can be increased or decreased as the changing head demands. In Imperial Valley, the submerged orifice has come into general use, largely because the water from the Colorado River is so heavily charged with silt that the use of weirs is unsatisfactory.

The measurement of water in terms of the miner's inch is practically universal in most of the foothill and citrus orchard sections of the state. In these areas, where irrigation water is bought and paid for on the basis of the miner's inch, special devices are in general use by which a flow can be measured directly in that unit without the necessity of transposing from the more common units of the other parts of the state. Where individual pumping plants are in use water is commonly measured in terms of gallons per minute.

The common method of payment for irrigation water in an area has had a great influence in determining the method of measurement in that area. In most cases that method of measurement is used which can be most readily changed into the terms necessary for the computation of the water charges.

In addition to descriptions of the devices used with these common methods of measurement, which are familiar to most users of irrigation water, descriptions of a few unusual devices have been included, either because of the different theory involved, or because the devices seem well suited to a greater use in California.

The tables for weir discharge and for flow through submerged orifices of fixed openings are the most recent and the most reliable that are available. The United States Reclamation Service and the United States Department of Agriculture, Division of Irrigation Investigations, have willingly furnished tables.

UNITS OF WATER MEASUREMENT AND EQUIVALENTS

Cubic foot per second.—This unit represents an exact and definite quantity of water, viz: the equivalent of a stream one foot wide and one foot deep flowing at the rate of one foot per second.

24-hour second foot.—This is one cubic foot per second, running continuously throughout a 24-hour period. It is equivalent to approximately two (exactly 1.9834) acre-feet.

Acre-Foot.—This is the equivalent of a body of water one acre in area and one foot deep, or 43,560 cubic feet. One cubic foot per second, or fifty southern California inches, or forty California statute inches, running continuously for twenty-four hours will supply approximately two (exactly 1.9834) acre-feet.

Acre-Inch.—This is one-twelfth of one acre-foot, or the equivalent of a sheet of water one acre in area and one inch deep. It is the unit sometimes used instead of the acre-foot, especially in expressing quantities of less than one acre-foot. One cubic foot per second running continuously for one hour will supply approximately one acre-inch.

Gallon.—As many irrigators receive their water supply from pumps and as pump manufacturers usually estimate discharges in gallons per minute or per second, this is sometimes a convenient unit to use. One cubic foot is approximately equal to 7½ gallons (exactly 7.4805) and one cubic foot per second is approximately equivalent to 450 gallons per minute or 7½ gallons per second.

One thousand gallons.—This unit is quite common in irrigation practice in San Diego County, California.

Inch.—This is a variable unit having different meanings in different states and even in different sections of the same state. The old miner's inch of California was the quantity of water flowing freely through an opening one inch square, the center of which was four inches below the surface of the water standing above the opening; it is equivalent to a flow of nine gallons per minute or 1/50

cubic foot per second. The present statute inch of California is defined as a flow of one and one-half cubic feet per minute. It is measured through an orifice one inch square under a six-inch pressure and is equivalent to a flow of 11¼ gallons per minute or 1/40 cubic foot per second. While the meaning of the inch varies with local practice, it is not a stream of water one inch deep and one inch wide, regardless of pressure. Where its meaning is clear, the inch is a convenient unit for measuring small streams up to, say 50 to 100 inches, and is quite frequently used for such streams, particularly on many of the southern California systems. For larger streams its use is generally discarded in favor of the more definite unit, cubic foot per second.

24-hour inch.—This is a very common unit, especially in southern California, and is, as its name implies, one inch (the exact amount of which varies with locality and local custom) running for twenty-four hours. Variations of this unit found on some California irrigation systems are the one-hour inch and the twelve-hour inch.

The following table will be found useful in changing the expression of a quantity of water from one of these units to another:

	Southern California miner's inch	Statute miner's inch	Gallons per minute	Cubic feet per second	Acre-inch	Acre-foot
1 southern California miner's inch equals....	.....	1.25	9.0	$\frac{1}{50}$	1 in 50 hours	1 in 600 hours
1 Stat. miner's inch equals....	0.80	.....	11.25	$\frac{1}{40}$	1 in 40 hours	1 in 480 hours
1 gallon per minute equals	$\frac{1}{9}$	$\frac{1}{11.25}$	.....	$\frac{1}{450}$	1 in 450 hours	1 in 5400 hours
1 cubic foot per second equals	50	40	450	.....	1 in 1 hour	1 in 12 hours

WEIRS

A weir is one of the simplest and most accurate means of measuring irrigation water on the farm. The weir of the irrigation farmer is simply a bulkhead or wall placed across a stream, with an opening cut in the top through which the water is allowed to pass. This opening is commonly called the "weir notch." The depth of the water pouring through the weir notch is the measure of the amount of water in the stream. By gauging this depth and consulting the weir table for the kind and length of the weir notch used the amount of water passing over the weir is obtained.

In some cases the weir bulkhead is placed in a short section of flume, called a weir box; in others it is placed directly across an earth ditch and is independent of any other structure. (Fig. 1.) The theory and method of weir measurement remain the same in either case.

There are certain conditions which must be observed before a weir can be used for the accurate measurement of water. In general

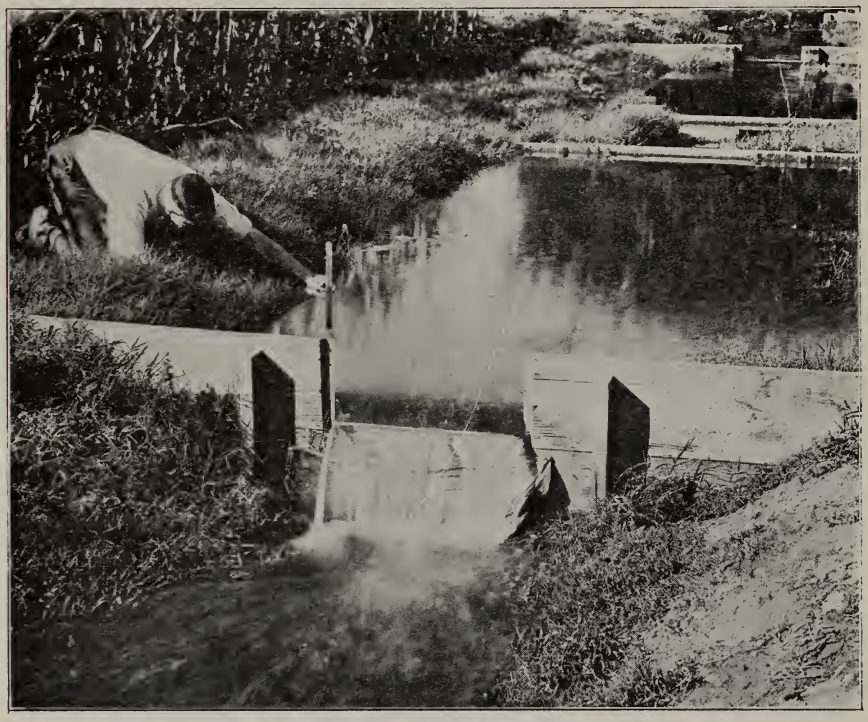

Fig. 1. Rectangular field weir in use.

it may be said that the "weir crest" or bottom of the weir notch should be short enough so that the amount of water to be measured will never give a depth of less than two inches over the crest, and long enough so that the depth will never be more than one-third of the length of the crest. Care should also be taken to see that the weir crest is long enough so that the water can pour through the notch without having to back up in the channel to a greater height than can be done with safety to the ditch bank. A number of other conditions are usually laid down as necessary for the weir. The most important of these are as follows:

1. The weir crest or bottom of the weir notch must be absolutely level.

2. The water passing over the weir must have a free "over-fall." If the water in the ditch below the weir is allowed to rise to such a height that this free fall is not possible, the weir is said to be submerged. Measurements made on a submerged weir are unreliable unless complicated corrections are introduced.

3. The distance from the crest of the weir to the bottom of the canal or to the floor of the weir box above the weir crest need only be great enough to check the velocity of water flowing in the bottom of the stream, say about 0.5 foot for small weirs.

4. The distance from the ends of the weir crest to the sides of the weir box or canal or ditch should be about twice the depth of the water on the weir, or, say from ten to twelve inches in the case of a weir with an eighteen-inch crest measuring about two cubic feet per second.

5. The bottom and sides of the weir notch should have a narrow edge. The use of a galvanized iron crest to give such a narrow edge is quite common and very satisfactory but not necessary. Sometimes thin pieces of strap iron are fastened on the up-stream side of the weir notch. In other cases the board in which the weir notch is cut is merely beveled on the down-stream side to a crest thickness of one-eighth or one-quarter of an inch.

6. Water should not be allowed to approach the weir with a velocity exceeding six inches per second. Also, it should flow to the weir in a smooth stream free from eddies or swirls. Both of these conditions are most easily met by placing the weir in a straight section of the ditch and, when necessary, by placing baffle boards across the channel.

7. The depth of water on the weir crest must be measured sufficiently above the weir to be free from the downward curve of the water as it passes over the weir. For convenience in making this measurement of depth a stake with its top level with the crest of the weir is usually set at one side of the ditch two or three feet above the weir, the measurements of depth being made from the top of this stake to the surface of the water.

It will be noted from these conditions that the weir is not a suitable means of measuring water under all conditions. In ditches where the grade is very slight, placing a bulkhead across a stream and raising the level of the water above the weir often results in a break in the ditch bank. In such cases it is also difficult to keep the weir from becoming submerged.

In streams heavily laden with silt the weir is not a practical means of measurement. Reducing the velocity of the water to the

point necessary for weir measurements soon precipitates such a quantity of solid matter above the weir that suitable weir conditions no longer exist.

By itself, a weir, measures a rate of flow and does not indicate the total quantity delivered. In conjunction with a water register, which keeps a graphic record of the changing depth of water over the weir, a permanent record is obtained from which the total quantity of water can be easily computed.

WEIR NOTCHES

There are three types of weir notches in common use, viz: rectangular weirs, Cipolletti weirs, and triangular weirs. Special tables have been devised for each of these. It is of course essential that the proper table be used for the weir crest selected.*

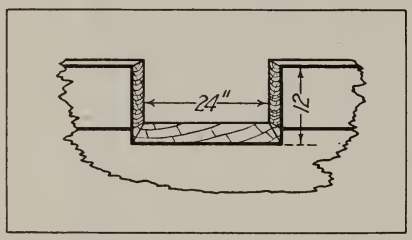

Fig. 2. Two foot rectangular weir notch.

RECTANGULAR WEIRS

The name is taken from the shape of the weir notch, shown in figure 2. This weir is also known sometimes as the Francis weir. It is one of the earliest forms of weirs used and is the type from which all other forms have been developed. Because of the simplicity, ease of construction, and accuracy with which the crest and sides may be set with the implements ordinarily at hand, this type of weir should be used more widely than it has been in the past. It is as accurate as the other types. The crest is placed in a horizontal position and the sides extend vertically above the crest. A right angle is therefore formed, which permits the weir to be made and set easily and accurately by means of a carpenter's square and level. The sides must be placed carefully to give the desired length along the crest. Table 1 gives the discharge over rectangular weirs from one to four feet in length, computed from the corrected formula:

* The discussion of "rectangular weirs," "Cipolletti weirs" and "90-degree triangular notch weirs," together with the discharge tables for these weir notches, is copied largely from Farmers' Bulletin No. 813, entitled "Construction and Use of Farm Weirs," by Victor M. Cone.

TABLE 1

Discharge Table for Rectangular Weirs

Head in feet	Head in inches	Discharge in cubic feet per second for crests of various lengths					Head in feet	Head in inches	Discharge in cubic feet per second for crests of various lengths				
		1 foot	1.5 feet	2 feet	3 feet	4 feet			1 foot	1.5 feet	2 feet	3 feet	4 feet
0.20	2⅜	0.291	0.439	0.588	0.887	1.19	.86	10⅜	2.46	3.72	5.01	7.59	10.19
.21	2½	.312	.472	.632	.954	1.28	.87	10⅜	2.50	3.79	5.10	7.72	10.36
.22	2⅝	.335	.505	.677	1.02	1.37	.88	10⅜	2.54	3.85	5.18	7.85	10.54
.23	2¾	.358	.539	.723	1.09	1.46	.89	10½	2.58	3.92	5.27	7.99	10.71
.24	2⅞	.380	.574	.769	1.16	1.55	.90	10⅝	2.62	3.98	5.35	8.12	10.89
.25	3	.404	.609	.817	1.23	1.65	.91	10⅝	2.67	4.05	5.44	8.25	11.07
.26	3⅛	.428	.646	.865	1.31	1.75	.92	11⅛	2.71	4.11	5.53	8.38	11.25
.27	3¼	.452	.682	.914	1.38	1.85	.93	11⅜	2.75	4.18	5.62	8.52	11.43
.28	3⅜	.477	.720	.965	1.46	1.95	.94	11¼	2.79	4.24	5.71	8.65	11.61
.29	3½	.502	.758	1.02	1.53	2.05	.95	11⅜	2.84	4.31	5.80	8.79	11.79
.30	3⅝	.527	.796	1.07	1.61	2.16	.96	11½	2.88	4.37	5.89	8.93	11.98
.31	3¾	.553	.836	1.12	1.69	2.26	.97	11⅝	2.93	4.44	5.98	9.06	12.16
.32	3 13/16	.580	.876	1.18	1.77	2.37	.98	11¾	2.97	4.51	6.07	9.20	12.34
.33	3 15/16	.606	.916	1.23	1.86	2.48	.99	11⅞	3.01	4.57	6.15	9.34	12.53
.34	4 1/16	.634	.957	1.28	1.94	2.60	1.00	12	3.06	4.64	6.25	9.48	12.72
.35	4 3/16	.661	.999	1.34	2.02	2.71	1.01	12⅛	.....	4.71	6.34	9.62	12.91
.36	4 5/16	.688	1.04	1.40	2.11	2.82	1.02	12¼	.....	4.78	6.43	9.76	13.10
.37	4 7/16	.717	1.08	1.45	2.20	2.94	1.03	12⅜	.....	4.85	6.52	9.90	13.28
.38	4 9/16	.745	1.13	1.51	2.28	3.06	1.04	12½	.....	4.92	6.62	10.04	13.47
.39	4 11/16	.774	1.17	1.57	2.37	3.18	1.05	12⅝	.....	4.98	6.71	10.18	13.66
.40	4 13/16	.804	1.21	1.63	2.46	3.30	1.06	12¾	.....	5.05	6.80	10.32	13.85
.41	4 15/16	.833	1.26	1.69	2.55	3.42	1.07	12 13/16	.....	5.12	6.90	10.46	14.04
.42	5 1/16	.863	1.30	1.75	2.65	3.54	1.08	12 15/16	.....	5.20	6.99	10.61	14.24
.43	5 3/16	.893	1.35	1.81	2.74	3.67	1.09	13 1/16	.....	5.26	7.09	10.75	14.43
.44	5¼	.924	1.40	1.88	2.83	3.80	1.10	13 3/16	.....	5.34	7.19	10.90	14.64
.45	5⅜	.955	1.44	1.94	2.93	3.93	1.11	13 5/16	.....	5.41	7.28	11.04	14.83
.46	5½	.986	1.49	2.00	3.03	4.05	1.12	13 7/16	.....	5.48	7.38	11.19	15.03
.47	5⅝	1.02	1.54	2.07	3.12	4.18	1.13	13 9/16	.....	5.55	7.47	11.34	15.22
.48	5¾	1.05	1.59	2.13	3.22	4.32	1.14	13 11/16	.....	5.62	7.57	11.48	15.42
.49	5⅞	1.08	1.64	2.20	3.32	4.45	1.15	13 13/16	.....	5.69	7.66	11.64	15.62
.50	6	1.11	1.68	2.26	3.42	4.58	1.16	13 15/16	.....	5.77	7.76	11.79	15.82
.51	6⅛	1.15	1.73	2.33	3.52	4.72	1.17	14 1/16	.....	5.84	7.86	11.94	16.02
.52	6¼	1.18	1.78	2.40	3.62	4.86	1.18	14 3/16	.....	5.91	7.96	12.09	16.23
.53	6⅜	1.21	1.84	2.46	3.73	4.99	1.19	14¼	.....	5.98	8.06	12.24	16.43
.54	6½	1.25	1.89	2.53	3.83	5.13	1.20	14⅜	.....	6.06	8.16	12.39	16.63
.55	6⅝	1.28	1.94	2.60	3.94	5.27	1.21	14½	.....	6.13	8.26	12.54	16.83
.56	6¾	1.31	1.99	2.67	4.04	5.42	1.22	14⅝	.....	6.20	8.35	12.69	17.03
.57	6 13/16	1.35	2.04	2.74	4.15	5.56	1.23	14¾	.....	6.28	8.46	12.85	17.25
.58	6 15/16	1.38	2.09	2.81	4.26	5.70	1.24	14⅞	.....	6.35	8.56	12.99	17.45
.59	7 1/16	1.42	2.15	2.88	4.36	5.85	1.25	15	.....	6.43	8.66	13.14	17.65
.60	7 3/16	1.45	2.20	2.96	4.47	6.00	1.26	15⅛	.....	.....	.....	13.30	17.87
.61	7 5/16	1.49	2.25	3.03	4.59	6.14	1.27	15¼	.....	.....	.....	13.45	18.07
.62	7 7/16	1.52	2.31	3.10	4.69	6.29	1.28	15⅜	.....	.....	.....	13.61	18.28
.63	7 9/16	1.56	2.36	3.17	4.81	6.44	1.29	15½	.....	.....	.....	13.77	18.50
.64	7 11/16	1.60	2.42	3.25	4.92	6.59	1.30	15⅝	.....	.....	.....	13.93	18.71
.65	7 13/16	1.63	2.47	3.32	5.03	6.75	1.31	15¾	.....	.....	.....	14.09	18.92
.66	7 15/16	1.67	2.53	3.40	5.15	6.90	1.32	15 13/16	.....	.....	.....	14.24	19.12
.67	8 1/16	1.71	2.59	3.47	5.26	7.05	1.33	15 15/16	.....	.....	.....	14.40	19.34
.68	8 3/16	1.74	2.64	3.56	5.38	7.21	1.34	16 1/16	.....	.....	.....	14.56	19.55
.69	8¼	1.78	2.70	3.63	5.49	7.36	1.35	16 3/16	.....	.....	.....	14.72	19.77
.70	8⅜	1.82	2.76	3.71	5.61	7.52	1.36	16 5/16	.....	.....	.....	14.88	19.98
.71	8½	1.86	2.81	3.78	5.73	7.68	1.37	16 7/16	.....	.....	.....	15.04	20.20
.72	8⅝	1.90	2.87	3.86	5.85	7.84	1.38	16 9/16	.....	.....	.....	15.20	20.42
.73	8¾	1.93	2.93	3.94	5.97	8.00	1.39	16 11/16	.....	.....	.....	15.36	20.64
.74	8⅞	1.97	2.99	4.02	6.09	8.17	1.40	16 13/16	.....	.....	.....	15.53	20.86
.75	9	2.01	3.05	4.10	6.21	8.33	1.41	16 15/16	.....	.....	.....	15.69	21.08
.76	9⅛	2.05	3.11	4.18	6.33	8.49	1.42	17 1/16	.....	.....	.....	15.85	21.29
.77	9¼	2.09	3.17	4.26	6.45	8.66	1.43	17 3/16	.....	.....	.....	16.02	21.52
.78	9⅜	2.13	3.23	4.34	6.58	8.82	1.44	17¼	.....	.....	.....	16.19	21.74
.79	9½	2.17	3.29	4.42	6.70	8.99	1.45	17⅜	.....	.....	.....	16.34	21.96
.80	9⅝	2.21	3.35	4.51	6.83	9.16	1.46	17½	.....	.....	.....	16.51	22.18
.81	9¾	2.25	3.41	4.59	6.95	9.33	1.47	17⅝	.....	.....	.....	16.68	22.41
.82	9 13/16	2.29	3.47	4.67	7.08	9.50	1.48	17¾	.....	.....	.....	16.85	22.64
.83	9 15/16	2.33	3.54	4.75	7.21	9.67	1.49	17⅞	.....	.....	.....	17.01	22.85
.84	10 1/16	2.37	3.60	4.84	7.33	9.84	1.50	18	.....	.....	.....	17.17	23.08
.85	10 3/16	2.41	3.66	4.92	7.46	10.01							

CIPOLLETTI WEIRS

This type of weir is trapezoidal in shape, the name "Cipolletti" being that of the Italian engineer who proposed its use. As shown in figure 3, the crest of the weir, or bottom of the weir notch, must be level, and the sides placed on a slope of one to four, meaning one unit horizontal to four units vertical. The notch therefore is larger than a rectangle with the same crest length.

It is readily seen that the Cipolletti type of weir, or in fact any weir having sloping sides, is not so easy either to construct or to check for accurracy as is the rectangular weir. The great popularity of the Cipolletti weir is due somewhat to its having been proposed

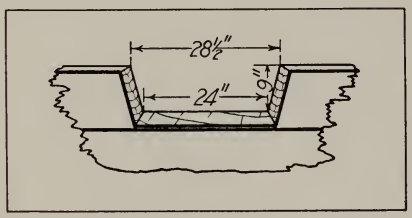

Fig. 3. Two foot Cipolletti weir notch.

at a time when the use of weirs for measuring irrigation water was being considered, but principally because the angle which the sides make with the crest was supposed to make the flow over the weir proportional to the length of the crest. In other words, the flow for a certain head on a two-foot weir was supposed to be twice the flow over a one-foot weir for the same depth of water, which would require but a simple weir table for field use. Recent experiments, however, prove that the flow over Cipolletti weirs is not proportional to the length of the crest, which apparently refutes the principal argument in its favor. However, if the sides are placed properly with respect to the crest, and other conditions are observed fully, the flow can be measured as accurately over a Cipolletti weir as over a rectangular weir, by use of the accompanying weir tables, or formula. It is all right, therefore, to use a Cipolletti weir if built properly, but where a weir is to be constructed, the rectangular should be chosen in preference to the Cipolletti type. Table 2 gives the discharge over Cipolletti weirs from one to four feet in length, computed from the corrected formula.

TABLE 2

Discharge Table for Cipolletti Weirs

Head in feet	Head in inches	Discharge in cubic feet per second for crests of various lengths					Head in feet	Head in inches	Discharge in cubic feet per second for crests of various lengths				
		1 foot	1.5 feet	2 feet	3 feet	4 feet			1 foot	1.5 feet	2 feet	3 feet	4 feet
0.20	2 3/8	0.30	0.45	0.60	0.90	1.20	.86	10 5/16	2.87	4.14	5.43	8.01	10.60
.21	2 1/2	.32	.48	.64	.97	1.29	.87	10 7/16	2.93	4.22	5.52	8.15	10.79
.22	2 5/8	.35	.52	.69	1.04	1.38	.88	10 9/16	2.98	4.29	5.62	8.30	10.98
.23	2 3/4	.37	.55	.74	1.11	1.47	.89	10 11/16	3.04	4.37	5.72	8.44	11.17
.24	2 7/8	.39	.59	.79	1.18	1.57	.90	10 13/16	3.09	4.45	5.82	8.59	11.36
.25	3	.42	.63	.84	1.25	1.67	.91	10 15/16	3.15	4.53	5.92	8.73	11.55
.26	3 1/8	.45	.67	.89	1.33	1.77	.92	11 1/16	3.20	4.60	6.02	8.88	11.74
.27	3 1/4	.47	.70	.94	1.40	1.87	.93	11 3/16	3.26	4.68	6.13	9.03	11.94
.28	3 3/8	.50	.74	.99	1.48	1.97	.94	11 1/4	3.32	4.76	6.23	9.17	12.13
.29	3 1/2	.53	.79	1.04	1.56	2.08	.95	11 3/8	3.37	4.84	6.33	9.32	12.33
.30	3 5/8	.56	.83	1.10	1.64	2.19	.96	11 1/2	3.43	4.92	6.44	9.48	12.53
.31	3 3/4	.59	.87	1.15	1.73	2.30	.97	11 5/8	3.49	5.00	6.55	9.62	12.72
.32	3 13/16	.61	.91	1.21	1.80	2.41	.98	11 3/4	3.55	5.09	6.64	9.78	12.92
.33	3 15/16	.64	.95	1.27	1.89	2.52	.99	11 7/8	3.61	5.17	6.75	9.93	13.12
.34	4 1/16	.67	1.00	1.32	1.98	2.64	1.00	12	3.67	5.25	6.86	10.08	13.32
.35	4 3/16	.70	1.04	1.38	2.07	2.75	1.01	12 1/8	.....	5.33	6.96	10.24	13.53
.36	4 5/16	.73	1.09	1.44	2.16	2.87	1.02	12 1/4	.....	5.42	7.07	10.40	13.73
.37	4 7/16	.77	1.13	1.50	2.25	2.99	1.03	12 3/8	.....	5.50	7.18	10.55	13.94
.38	4 9/16	.80	1.18	1.57	2.34	3.11	1.04	12 1/2	.....	5.59	7.29	10.71	14.15
.39	4 11/16	.83	1.23	1.63	2.43	3.24	1.05	12 5/8	.....	5.67	7.40	10.87	14.35
.40	4 13/16	.87	1.28	1.69	2.53	3.36	1.06	12 3/4	.....	5.76	7.51	11.03	14.56
.41	4 15/16	.90	1.32	1.76	2.62	3.49	1.07	12 13/16	.....	5.84	7.62	11.18	14.76
.42	5 1/16	.93	1.37	1.82	2.72	3.61	1.08	12 15/16	.....	5.93	7.73	11.35	14.98
.43	5 3/16	.97	1.42	1.89	2.81	3.74	1.09	13 1/16	.....	6.02	7.84	11.51	15.19
.44	5 1/4	1.00	1.47	1.95	2.91	3.87	1.10	13 3/16	.....	6.11	7.96	11.68	15.41
.45	5 3/8	1.04	1.53	2.02	3.01	4.01	1.11	13 5/16	.....	6.20	8.07	11.84	15.62
.46	5 1/2	1.07	1.58	2.09	3.11	4.14	1.12	13 7/16	.....	6.29	8.18	12.00	15.84
.47	5 5/8	1.11	1.63	2.16	3.21	4.28	1.13	13 9/16	.....	6.37	8.29	12.16	16.04
.48	5 3/4	1.15	1.68	2.23	3.32	4.41	1.14	13 11/16	.....	6.46	8.41	12.33	16.26
.49	5 7/8	1.18	1.74	2.30	3.42	4.55	1.15	13 13/16	.....	6.56	8.53	12.50	16.48
.50	6	1.22	1.79	2.37	3.53	4.69	1.16	13 15/16	.....	6.65	8.65	12.67	16.70
.51	6 1/8	1.26	1.85	2.44	3.64	4.83	1.17	14 1/16	.....	6.74	8.76	12.84	16.93
.52	6 1/4	1.30	1.90	2.51	3.74	4.97	1.18	14 3/16	.....	6.83	8.88	13.01	17.15
.53	6 3/8	1.34	1.96	2.59	3.85	5.12	1.19	14 1/4	.....	6.93	9.10	13.18	17.37
.54	6 1/2	1.38	2.02	2.66	3.96	5.26	1.20	14 3/8	.....	7.02	9.12	13.35	17.59
.55	6 5/8	1.42	2.07	2.74	4.07	5.41	1.21	14 1/2	.....	7.11	9.24	13.52	17.81
.56	6 3/4	1.46	2.13	2.81	4.18	5.56	1.22	14 5/8	.....	7.20	9.36	13.69	18.03
.57	6 13/16	1.50	2.19	2.89	4.30	5.71	1.23	14 3/4	.....	7.30	9.48	13.87	18.27
.58	6 15/16	1.54	2.25	2.97	4.41	5.86	1.24	14 7/8	.....	7.40	9.60	14.04	18.49
.59	7 1/16	1.58	2.31	3.05	4.53	6.01	1.25	15	.....	7.49	9.72	14.21	18.71
.60	7 3/16	1.62	2.37	3.13	4.64	6.17	1.26	15 1/8	.....	.....	.....	14.39	18.95
.61	7 5/16	1.67	2.43	3.20	4.76	6.32	1.27	15 1/4	.....	.....	.....	14.56	19.17
.62	7 7/16	1.71	2.49	3.28	4.88	6.47	1.28	15 3/8	.....	.....	.....	14.74	19.41
.63	7 9/16	1.75	2.55	3.37	5.00	6.63	1.29	15 1/2	.....	.....	.....	14.92	19.65
.64	7 11/16	1.80	2.62	3.45	5.12	6.79	1.30	15 5/8	.....	.....	.....	15.11	19.88
.65	7 13/16	1.84	2.68	3.53	5.24	6.95	1.31	15 3/4	.....	.....	.....	15.29	20.12
.66	7 15/16	1.89	2.75	3.61	5.36	7.11	1.32	15 13/16	.....	.....	.....	15.46	20.34
.67	8 1/16	1.93	2.81	3.70	5.48	7.28	1.33	15 15/16	.....	.....	.....	15.64	20.58
.68	8 3/16	1.98	2.87	3.79	5.61	7.44	1.34	16 1/16	.....	.....	.....	15.82	20.82
.69	8 1/4	2.02	2.94	3.87	5.73	7.61	1.35	16 3/16	.....	.....	.....	16.01	21.06
.70	8 3/8	2.07	3.01	3.95	5.86	7.77	1.36	16 5/16	.....	.....	.....	16.19	21.29
.71	8 1/2	2.12	3.07	4.04	5.99	7.94	1.37	16 7/16	.....	.....	.....	16.37	21.53
.72	8 5/8	2.16	3.14	4.13	6.12	8.11	1.38	16 9/16	.....	.....	.....	16.57	21.78
.73	8 3/4	2.21	3.21	4.22	6.24	8.28	1.39	16 11/16	.....	.....	.....	16.75	22.02
.74	8 7/8	2.26	3.28	4.31	6.38	8.45	1.40	16 13/16	.....	.....	.....	16.94	22.27
.75	9	2.31	3.35	4.40	6.51	8.62	1.41	16 15/16	.....	.....	.....	17.13	22.51
.76	9 1/8	2.36	3.42	4.49	6.64	8.80	1.42	17 1/16	.....	.....	.....	17.31	22.75
.77	9 1/4	2.41	3.49	4.58	6.77	8.97	1.43	17 3/16	.....	.....	.....	17.51	23.01
.78	9 3/8	2.46	3.56	4.67	6.90	9.15	1.44	17 1/4	.....	.....	.....	17.70	23.26
.79	9 1/2	2.51	3.63	4.76	7.04	9.33	1.45	17 3/8	.....	.....	.....	17.89	23.50
.80	9 5/8	2.56	3.70	4.85	7.18	9.51	1.46	17 1/2	.....	.....	.....	18.08	23.75
.81	9 3/4	2.61	3.77	4.95	7.31	9.69	1.47	17 5/8	.....	.....	.....	18.28	24.01
.82	9 13/16	2.66	3.84	5.04	7.45	9.87	1.48	17 3/4	.....	.....	.....	18.47	24.26
.83	9 15/16	2.71	3.92	5.14	7.59	10.05	1.49	17 7/8	.....	.....	.....	18.66	24.50
.84	10 1/16	2.77	3.99	5.23	7.73	10.23	1.50	18	.....	.....	.....	18.85	24.75
.85	10 3/16	2.82	4.07	5.33	7.87	10.42							

90-DEGREE TRIANGULAR-NOTCH WEIRS

This type of weir (Fig. 4) deserves to be more widely used than at present for the measurement of small quantities of water to the irrigator. If sufficient fall is available it may be used for flows as great as fourteen second-feet, which would be obtained with a depth of practically two feet of water above the vertex, or lowest point, of the angle formed by the sides. However, conditions usually are not favorable for its use for such large heads, and table 3 gives the discharge for heads up to 1.25 feet. Since the sides meet at a point with no length of crest, a small flow of water that would not pass over one of the other weirs without adhering to the crest and therefore making the measurement worthless, will flow free in the ninety-degree

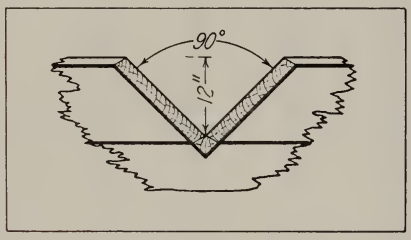

Fig. 4. 90° weir notch.

triangular notch and may be measured accurately. The ninety-degree triangular notch is especially applicable from small flows up to two or three cubic feet per second. Because of the greater depth of water required for this type of weir to discharge a given quantity of water, and the consequent greater loss of head, one of the other types of weirs usually will be better adapted to large quantities of water. Experiments have shown that the rectangular and Cipolletti weirs with six-inch crest lengths do not follow the same laws of discharge as the longer weirs, and the discharge formulae given in this circular for these weirs do not apply to weirs with a crest length of six inches or less. Therefore, where only a small flow of water is to be measured the use of the ninety-degree triangular notch is especially recommended.

The sides of the ninety-degree triangular notch may be set readily by means of a carpenter's square and level. The notch can be marked out properly by placing the point of the angle between the arms of a carpenter's square at a point which is to be the bottom of the notch and adjusting the square so that the same figures on

both arms of the square are at the edge of the board, then if the board is set level the notch will be in the proper position. The sides, therefore, have the same slope.

Table 3 gives the discharge over the ninety-degree triangular notch, computed from the corrected formula:

TABLE 3

DISCHARGE TABLE FOR 90° TRIANGULAR NOTCH

Head in feet	Head in inches	Discharge in second-feet (Q)	Head in feet	Head in inches	Discharge in second-feet (Q)	Head in feet	Head in inches	Discharge in second-feet (Q)
0.20	2⅜	0.046	0.55	6⅝	0.564	0.90	10 13/16	1.92
.21	2½	.052	.56	6¾	.590	.91	10 15/16	1.97
.22	2⅝	.058	.57	6 13/16	.617	.92	11 1/16	2.02
.23	2¾	.065	.58	6 15/16	.644	.93	11 3/16	2.08
.24	2⅞	.072	.59	7 1/16	.672	.94	11¼	2.13
.25	3	.080	.60	7 3/16	.700	.95	11⅜	2.19
.26	3⅛	.088	.61	7 5/16	.730	.96	11½	2.25
.27	3¼	.096	.62	7 7/16	.760	.97	11⅝	2.31
.28	3⅜	.106	.63	7 9/16	.790	.98	11¾	2.37
.29	3½	.115	.64	7 11/16	.822	.99	11⅞	2.43
.30	3⅝	.125	.65	7 13/16	.854	1.00	12	2.49
.31	3¾	.136	.66	7 15/16	.887	1.01	12⅛	2.55
.32	3 13/16	.147	.67	8 1/16	.921	1.02	12¼	2.61
.33	3 15/16	.159	.68	8 3/16	.955	1.03	12⅜	2.68
.34	4 1/16	.171	.69	8¼	.991	1.04	12½	2.74
.35	4 3/16	.184	.70	8⅜	1.03	1.05	12⅝	2.81
.36	4 5/16	.197	.71	8½	1.06	1.06	12¾	2.87
.37	4 7/16	.211	.72	8⅝	1.10	1.07	12 13/16	2.94
.38	4 9/16	.226	.73	8¾	1.14	1.08	12 15/16	3.01
.39	4 11/16	.240	.74	8⅞	1.18	1.09	13 1/16	3.08
.40	4 13/16	.256	.75	9	1.22	1.10	13 3/16	3.15
.41	4 15/16	.272	.76	9⅛	1.26	1.11	13 5/16	3.22
.42	5 1/16	.289	.77	9¼	1.30	1.12	13 7/16	3.30
.43	5 3/16	.306	.78	9⅜	1.34	1.13	13 9/16	3.37
.44	5¼	.324	.79	9½	1.39	1.14	13 11/16	3.44
.45	5⅜	.343	.80	9⅝	1.43	1.15	13 13/16	3.52
.46	5½	.362	.81	9¾	1.48	1.16	13 15/16	3.59
.47	5⅝	.382	.82	9 13/16	1.52	1.17	14 1/10	3.67
.48	5¾	.403	.83	9 15/16	1.57	1.18	14 3/16	3.75
.49	5⅞	.424	.84	10 1/16	1.61	1.19	14¼	3.83
.50	6	.445	.85	10 3/16	1.66	1.20	14⅜	3.91
.51	6⅛	.468	.86	10 5/16	1.71	1.21	14½	3.99
.52	6¼	.491	.87	10 7/16	1.76	1.22	14⅝	4.07
.53	6⅜	.515	.88	10 9/16	1.81	1.23	14¾	4.16
.54	6½	.539	.89	10 11/16	1.86	1.24	14⅞	4.24
						1.25	15	4.33

WEIR CONSTRUCTION

The type of the soil in which a weir is to be placed is important in determining whether a simple weir board or a more elaborate weir box should be used. In heavy clay soils where excessive washing of the soil does not occur, a simple bulkhead placed across the stream can be used. In lighter soils where the washing out of ditch structures is liable to occur, a weir box is necessary.

Figure 5 is an isometric drawing of a simple weir bulkhead which can be easily constructed on the farm. Table 4 gives the sizes of

weirs and weir bulkheads best adapted for the measuring of heads of water from one-half cubic foot per second to thirteen cubic feet per second. The letters at the heads of the columns refer to the dimensions as shown in figure 5:

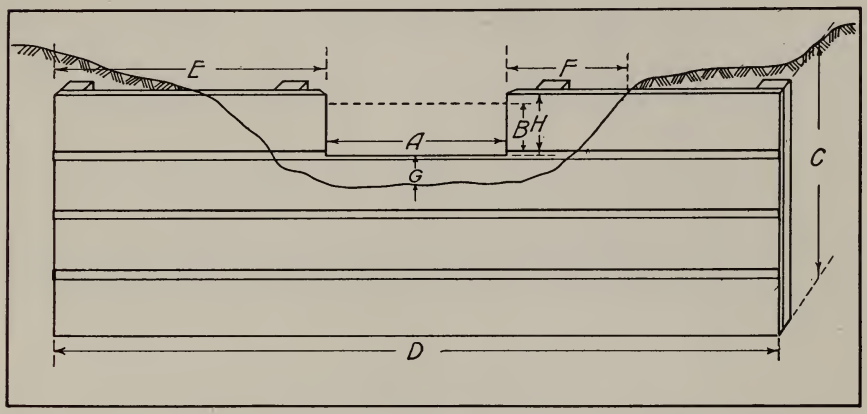

Fig. 5. Isometric drawing of weir bulkhead. Suitable only for rather heavy soil.

TABLE 4

Weir Board Dimensions for Rectangular and Cipolletti Weirs

Letters at head of columns refer to figure 5.

Capacity of weir, cubic feet per second	Length of crest, A, feet	Maximum head over weir crest, B, feet	Depth of notch, H, feet	Total depth of bulkhead C, feet	Total length of bulk-head, D, feet	Distance of crest, G, above ditch bottom, ft.	Length of wing, E, feet	Distance of edge of notch, F, from ditch bank, feet
½ to 2	1.5	.56	1.0	3.0	10.0	0.3	4.25	1.5
1 to 7½	3.0	.86	1.0	4.0	12.0	0.5	4.50	2.0
1½ to 13	4.0	1.00	1.5	5.0	16.0	0.7	6.00	2.5

With rectangular or Cipolletti weirs, as previously stated, the head of water can best be measured from a stake driven in the ditch bank or bottom to the elevation of the weir crest and about three feet upstream from the crest. The stake can be easily set with an accurate carpenter's level. The depth of water over this stake, as shown by a carpenter's rule, will then measure the depth of water passing over the weir.

Figure 6 shows the construction of a complete weir box. The letters refer to table 5, which shows the dimensions of these boxes as built for measuring heads of water from one-half cubic foot per second to seventeen cubic feet per second:

TABLE 5

DIMENSIONS FOR WEIR BOXES AS SHOWN IN FIGURE 6

Letters at head of columns refer to figure 6.

Capacity of weir, cubic feet per second	Length of crest, A, feet	Maximum head over weir, B, feet	Total depth of notch, H, feet	Total depth of bulkhead, C, feet	Total length of bulkhead, D, feet	Distance of crest above ditch bottom, G, feet	Length of wing, E, feet	Edge of notch, F, from ditch bank, feet	Distance between bulkheads, I, feet	Distance of crest above overflow of water cushion, M, feet
½ to 2½	1.5	.67	1.0	3.0	10.0	0.3	4.25	1.5	3.0	1.0
2 to 7½	3.0	.86	1.0	4.0	12.0	0.5	4.50	2.0	3.0	1.2
6 to 17	4.0	1.20	1.5	5.0	16.0	0.7	6.00	2.5	3.5	1.4

NOTE.—In all cases assumed in figure 6 the water cushion below the weir crest is 6 inches deep, although any depth that will give sufficient pool to break the fall of the water, in order to prevent ditch erosion below, is satisfactory. The overflow from this cushion should be on the grade of the ditch bottom as it leaves the structure. In the last column of the table, definite distances of crest, M, above the overflow of the water cushion are assumed, because these distances are ample. Any drop, however, that permits a free fall of the water over the weir crest meets the conditions required by the weir formula.

SUBMERGED ORIFICES

In cases where the grade of ditch is so flat that the required free fall over a weir can not be easily obtained, and in cases where the waters are so heavily charged with silt that there is danger of a weir pond silting up, some type of submerged orifice is commonly used.

The measurement of water through orifices has long been common in irrigation practice and various forms of orifices have been

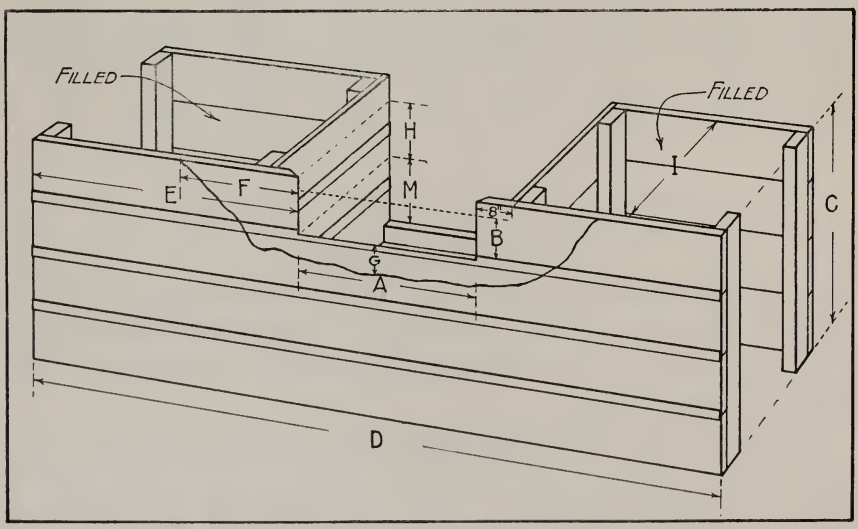

Fig. 6. Isometric drawing of weir bulkhead. Designed for light soils.

developed. The essential condition in the use of an orifice, eliminating the question of form, is that the water on the up-stream side of the orifice shall completely submerge it. If, when in use, the surface of the water on the lower side of the orifice is below the bottom thereof, the orifice is said to have a free discharge. If the surface of the water on the lower side of the orifice is above the top of the

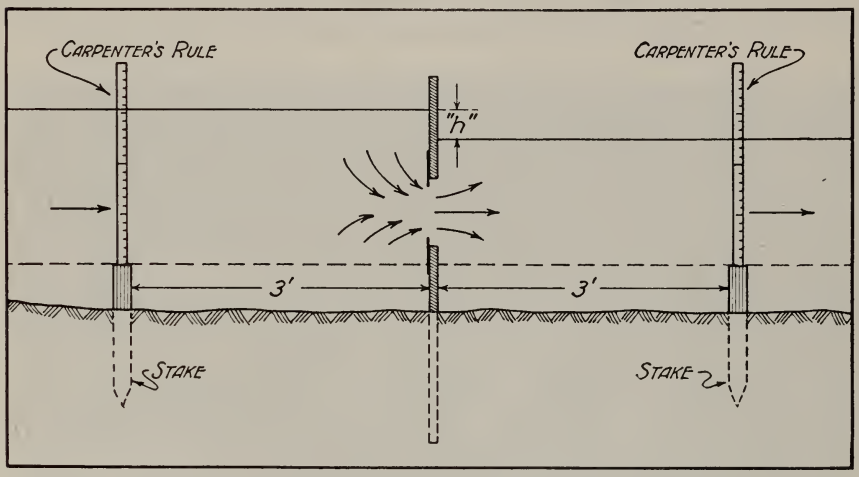

Fig. 7. Diagrammatic sketch showing orifice of fixed dimensions in use.

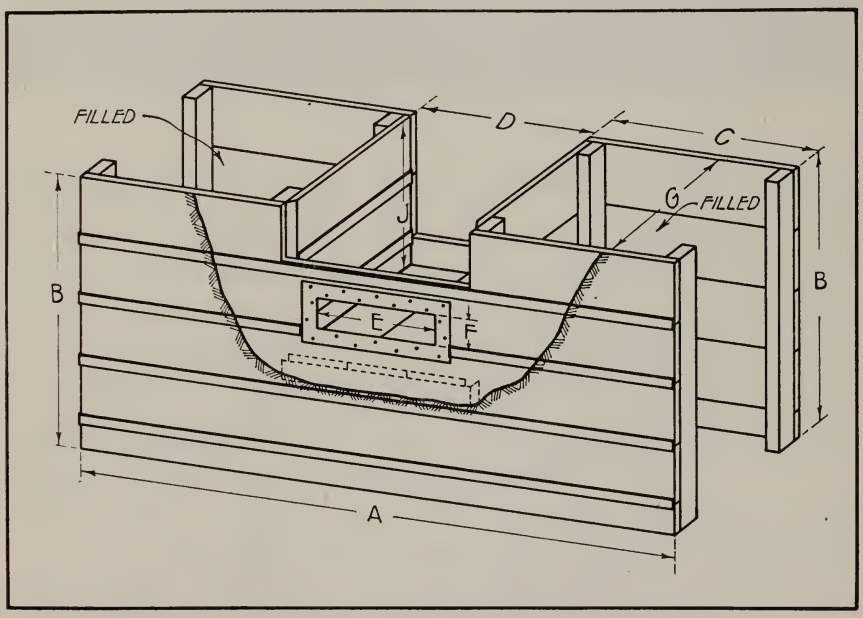

Fig. 8. Isometric drawing of U.S.R.S. submerged orifice.

orifice, completely submerging it, it is classed as a submerged orifice. Except in the case of the miner's inch box, which is really but a form of orifice with free discharge, use of the orifice in irrigation practice is mainly confined in California to the submerged form.

Submerged orifices as used can be divided into two general types, viz: those with orifices of fixed dimensions (Fig. 8) and those built so that the height of the opening may be varied (Figs. 9 and 10).

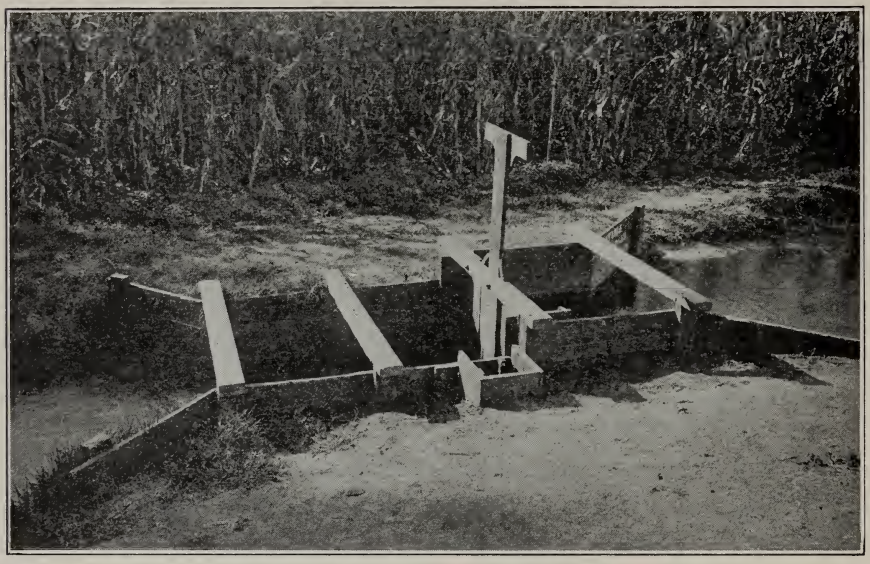

Fig. 9. Photograph of adjustable submerged orifice in use.

Orifices of fixed dimensions are usually made with sharp edges similar to the crest of a weir. The most usual type of adjustable orifice is the simple head gate, the height of opening and loss of head being adjusted to the amount which it is desired to turn out and to the loss of head available. Of these two types, the sharp-edged orifice of fixed dimensions is much the more accurate in practice.

With either of these types of submerged orifice, the quantity of water passing through the orifice is measured by the difference in water level above and below the orifice. Such a difference in water level always exists in devices of this sort. This difference in water level is commonly called the "difference in head" or "loss of head." A small "h" is usually used to represent this difference.

Figure 7 is a diagramatic sketch of a submerged orifice in use.

The amount of water which passes through a submerged orifice of fixed dimensions increases as "h" increases. Theoretically, if

"h" could be indefinitely increased, any quantity of water could be passed through an orifice with an area of one square foot. Practical difficulties make it impossible for this difference in head in small ditches ever to become larger than about eighteen inches. In ditches on very flat grades this difference in head can not become more than four or five inches without endangering the ditch bank above the orifice.

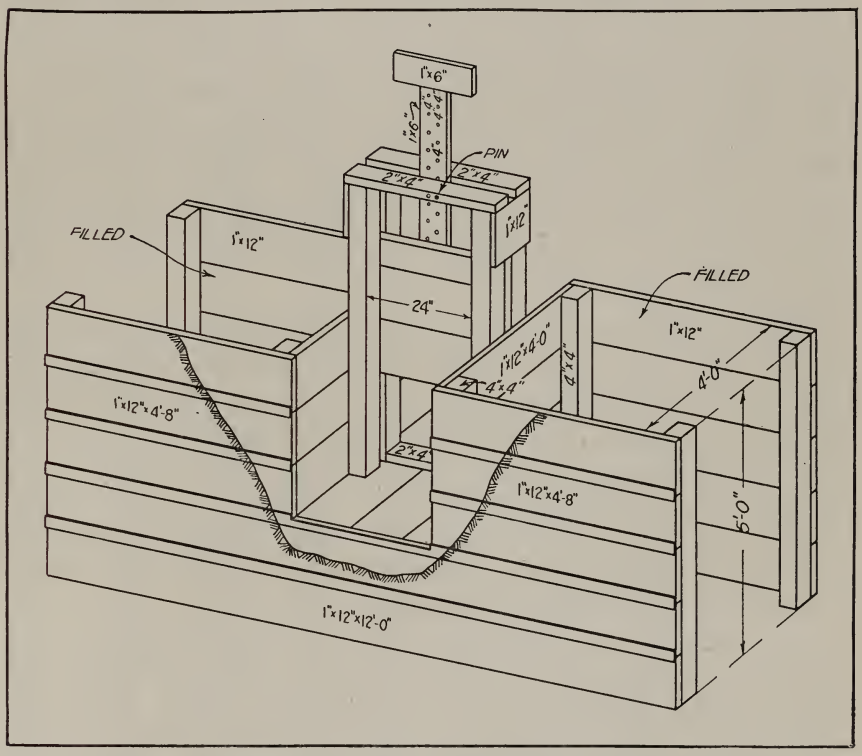

Fig. 10. Isometric drawing of adjustable submerged orifice.

In cases where sufficient discharge can not be obtained through the orifice with the loss in head that is permissible, a larger orifice may be used. With a given difference in head, the discharge is directly proportional to the area of the orifice and unreasonable difference in head can be reduced by increasing this area.*

* With crude adjustable submerged orifices, the statement that the discharge for a given loss of head is directly proportional to the area of the orifice is not strictly true. Work done by the Kern County Land Company shows that the value of "C" in the formula $v = C\sqrt{2gh}$ varies with changes in the area of the opening. The exact proportion is consequently destroyed.

SUBMERGED ORIFICE WITH FIXED DIMENSIONS

This type of submerged orifice is used for measurements only, the fixing of the size of the opening preventing its use as a headgate.

In order that the known formulae for the discharge through such orifices shall apply, certain standard conditions must be observed in their construction and use. The edges of the orifice must be sharp and definite in shape. It is preferable to use a thin metal plate as this is not subject to wear and change. The edges of the orifice should not be too near to the sides of the box on either the upper or lower sides; a distance equal to twice the least dimension of the orifice is sufficient. The sides of the orifice should be vertical and the bottom edge level. The ditch above the orifice should be sufficiently large so that the velocity of approach will be small, as is necessary in the case of a weir. Corrections can be made in the computations for any velocity of approach but such corrections are more or less uncertain.

The principal sources of error in measurements with this type of orifice are due to errors in the gauge readings to determine the difference in the elevation of the water on the two sides, this being the head or pressure that forces the water through the orifice. As these orifices are generally used where there is but little loss of head available, the opening is usually made sufficiently large to require as little loss of head as is practicable. Any error in reading this small loss of head is thus a larger percentage of the whole than it would be for greater total differences.

In the use of the submerged orifice two gauge readings are required, one above and one below the orifice. The reading above the orifice should be taken back from the edge of the orifice. In the type of structure shown in figures 8 and 10 this can be taken on the side wing wall. Perhaps a still better way is to drive two stakes in the bottom of the ditch, one of which should be about three feet above the orifice and the other three feet below. By driving these stakes to the same elevation and measuring the depth of water over each of them, the difference in head or "h" can be easily determined. This quantity is, of course, the difference between these two depths.

The type of orifice described above and illustrated in figure 8 has been adopted by the United States Reclamation Service for use where sufficient loss of head is not available for weirs. The data given below regarding the sizes of the structures, and the table of discharges (table 6) are taken from the publication of the Reclamation Service on the measurement of irrigation water and from their

standard plans for submerged orifices. The cost of one of these devices installed will vary from about $10 to $30.

TABLE 6

DISCHARGE OF SUBMERGED RECTANGULAR ORIFICES IN CUBIC FEET PER SECOND

Taken from "Hydraulic and Excavation Tables" published by the U. S. Reclamation Service

Head h, inches	Head h, feet	Cross-sectional area A of orifice, square feet							
		0.25	0.5	0.75	1.0	1.25	1.5	1.75	2.0
1/8	0.01	0.122	0.245	0.367	0.489	0.611	0.734	0.856	0.978
1/4	.02	0.173	0.346	0.518	0.691	0.864	1.037	1.210	1.382
3/8	.03	0.212	0.424	0.635	0.847	1.059	1.271	1.483	1.694
1/2	.04	0.245	0.489	0.734	0.978	1.223	1.468	1.712	1.957
5/8	.05	0.273	0.547	0.820	1.093	1.367	1.640	1.913	2.186
3/4	.06	0.300	0.599	0.899	1.198	1.497	1.797	2.097	2.396
13/16	.07	0.324	0.647	0.971	1.294	1.617	1.941	2.265	2.588
15/16	.08	0.346	0.691	1.037	1.383	1.729	2.074	2.420	2.766
1 1/16	.09	0.367	0.734	1.101	1.468	1.835	2.201	2.638	2.935
1 1/16	.10	0.387	0.773	1.160	1.557	1.933	2.320	2.707	3.094
1 1/16	.11	0.406	0.811	1.217	1.622	2.027	2.433	2.839	3.244
1 1/16	.12	0.424	0.847	1.271	1.694	2.118	2.542	2.965	3.389
1 1/16	.13	0.441	0.882	1.323	1.764	2.205	2.645	3.086	3.527
1 1 1/16	.14	0.458	0.915	1.373	1.830	2.287	2.745	3.203	3.660
1 1 1/16	.15	0.474	0.947	1.421	1.895	2.369	2.842	3.316	3.790
1 1 1/16	.16	0.489	0.978	1.467	1.956	2.445	2.934	3.423	3.912
2 1/16	.17	0.504	1.008	1.512	2.016	2.520	3.024	3.528	4.032
2 1/16	.18	0.519	1.037	1.556	2.075	2.593	3.112	3.631	4.150
2 1/4	.19	0.533	1.066	1.599	2.132	2.665	3.198	3.731	4.264
2 3/8	.20	0.547	1.094	1.641	2.188	2.735	3.282	3.829	4.376
2 1/2	.21	0.561	1.120	1.681	2.241	2.801	3.361	3.921	4.482
2 5/8	.22	0.574	1.148	1.722	2.926	2.870	3.464	4.018	4.592
2 3/4	.23	0.587	1.172	1.759	2.345	2.931	3.517	4.103	4.690
2 7/8	.24	0.600	1.198	1.797	2.396	2.995	3.599	4.193	4.792
3	.25	0.612	1.223	1.834	2.446	3.057	3.668	4.280	4.891
3 1/8	.26	0.624	1.247	1.871	2.494	3.117	3.741	4.365	4.988
3 1/4	.27	0.636	1.270	1.906	2.541	3.176	3.811	4.446	5.082
3 3/8	.28	0.646	1.294	1.942	2.589	3.236	3.883	4.530	5.178
3 1/2	.29	0.659	1.319	1.978	2.638	3.297	3.956	4.616	5.276
3 5/8	.30	0.670	1.339	2.009	2.678	3.347	4.017	4.687	5.356
3 3/4	.31	0.681	1.363	2.045	2.726	3.407	4.089	4.771	5.452
3 13/16	.32	0.692	1.382	2.073	2.764	3.455	4.146	4.837	5.528
3 15/16	.33	0.703	1.405	2.107	2.810	3.513	4.215	4.917	5.620
4 1/16	.34	0.713	1.426	2.139	2.852	3.565	4.278	4.991	5.704
4 1/16	.35	0.724	1.446	2.169	2.892	3.615	4.338	5.061	5.784
4 1/16	.36	0.734	1.467	2.201	2.934	3.667	4.401	5.135	5.868
4 1/16	.37	0.745	1.488	2.232	2.976	3.720	4.464	5.208	5.952
4 1/16	.38	0.754	1.508	2.262	3.016	3.770	4.524	5.278	6.032
4 1 1/16	.39	0.764	1.527	2.291	3.054	3.818	4.582	5.345	6.109
4 1 1/16	.40	0.774	1.547	2.321	3.094	3.867	4.641	5.415	6.188
4 1 1/16	.41	0.783	1.567	2.350	3.133	3.917	4.700	5.483	6.266
5 1/16	.42	0.792	1.585	2.377	3.170	3.962	4.754	5.547	6.339
5 1/16	.43	0.802	1.604	2.406	3.208	4.010	4.812	5.614	6.416
5 1/4	.44	0.811	1.622	2.433	3.244	4.055	4.866	5.677	6.488
5 3/8	.45	0.820	1.640	2.461	3.281	4.101	4.921	5.741	6.562
5 1/2	.46	0.829	1.659	2.489	3.318	4.147	4.977	5.807	6.636
5 5/8	.47	0.839	1.678	2.517	3.356	4.195	5.035	5.874	6.713
5 3/4	.48	0.847	1.695	2.542	3.389	4.237	5.084	5.931	6.778
5 7/8	.49	0.856	1.712	2.568	3.424	4.280	5.136	5.992	6.848
6	.50	0.865	1.729	2.594	3.458	4.323	5.188	6.052	6.917
6 1/8	.51	0.873	1.746	2.620	3.493	4.366	5.239	6.112	6.986
6 1/4	.52	0.882	1.763	2.645	3.527	4.409	5.290	6.172	7.054
6 3/8	.53	0.890	1.780	2.670	3.560	4.451	5.341	6.231	7.121
6 1/2	.54	0.898	1.797	2.695	3.593	4.491	5.390	6.288	7.186
6 5/8	.55	0.907	1.813	2.719	3.626	4.533	5.439	6.345	7.252
6 3/4	.56	0.915	1.830	2.745	3.660	4.575	5.490	6.405	7.320
6 13/16	.57	0.923	1.846	2.769	3.692	4.615	5.538	6.461	7.384
6 15/16	.58	0.931	1.862	2.794	3.725	4.656	5.587	6.518	7.450
7 1/16	.59	0.939	1.879	2.818	3.757	4.697	5.636	6.575	7.514
7 1/16	.60	0.947	1.895	2.842	3.790	4.737	5.684	6.632	7.579
7 1/16	.61	0.955	1.910	2.865	3.820	4.775	5.730	6.685	7.640
7 1/16	.62	0.963	1.925	2.887	3.850	4.812	5.775	6.737	7.700
7 3/16	.63	0.971	1.941	2.911	3.882	4.853	5.823	6.793	7.764
7 1 1/16	.64	0.978	1.956	2.934	3.912	4.890	5.868	6.846	7.824
7 1 3/16	.65	0.986	1.972	2.958	3.944	4.930	5.916	6.902	7.888

CONSTRUCTION OF SUBMERGED ORIFICES OF FIXED DIMENSIONS

Figure 8 is an isometric drawing of the type of submerged orifice in use on many of the United States Reclamation Service projects. Particular attention is called to the box below the orifice into which the water flows as it passes through the opening. Such construction adds strength to the structure, minimizes the danger of its washing out and lessens erosion below it.

Since structures of this sort must be built in various sizes to correspond to local conditions, the dimensions on the drawing (Fig. 8) are indicated by letters. The letters refer to table 7, which gives these dimensions in feet for boxes with various sizes of opening. In all cases, the width of the head wall must be great enough to extend across the ditch from the center line of the ditch bank on one side to the center line of the ditch bank on the other side.

TABLE 7

DIMENSIONS FOR STANDARD SIZES OF SUBMERGED RECTANGULAR ORIFICES

Letters showing dimensions refer to figure 8.

Size of Orifice			Head-wall height, B, feet	Box height, J, feet	Structure length, G, feet	Floor width, D, feet	Total width of structure A, feet	Length of wing, C, feet	Bottom of orifice above ditch bottom, H, feet
Height F, feet	Length E, feet	Area, sq. feet							
.25	1.0	.25	4.5	2.5	3.5	2.0	8.0	3.0	.25
.25	2.0	.50	4.5	2.5	3.5	3.0	10.0	3.5	.25
.25	3.0	.75	4.5	2.5	3.5	4.0	12.0	4.0	.25
.50	1.0	.50	4.5	2.5	3.5	2.0	8.0	3.0	.50
.50	1.50	.75	4.5	2.5	3.5	2.5	10.0	3.75	.50
.50	2.0	1.00	4.5	2.5	3.5	3.0	10.0	3.5	.50
.50	2.5	1.25	4.5	2.5	3.5	3.5	12.0	4.25	.50
.50	3.0	1.50	5.0	2.5	3.5	4.0	12.0	4.0	.50
.75	1.33	1.00	4.5	2.5	4.0	2.5	10.0	3.75	.70
.75	1.67	1.25	4.5	2.5	4.0	3.0	12.0	4.5	.70
.75	2.00	1.50	4.5	2.5	4.0	3.5	14.0	5.25	.70
.75	2.33	1.75	5.0	3.0	4.0	3.5	14.0	5.25	.70
.75	2.67	2.00	5.0	3.0	4.0	4.0	14.0	5.0	.70

COMPUTATIONS IF TABLES ARE NOT AVAILABLE

One of the advantages of the submerged orifice as a measuring device lies in the fact that tables are not absolutely necessary for a ready determination of the discharge. The two basic formulae are:

$$Q = A\,V$$

$$V = C\sqrt{2gh}$$

Where Q = discharge in cubic feet per second

A = area of orifice in square feet

V = velocity of water through opening in feet per second

C = a coefficient which is 0.61 for a sharp-edged fixed opening

g = acceleration of gravity or 32.16 feet per second

h = difference in head in feet

These two formulae can be combined into a single expression

$$Q = A \times 4.89 \times \sqrt{h}$$

With any sharp-edged fixed orifice, the square root of the difference in head, in feet or fractions of feet, above and below the orifice, multiplied by 4.89, multiplied by the area of the opening in square feet, will give the discharge through the opening in cubic feet per second.

Example:

Area of opening = 2 square feet
Measured difference in head = 0.35 feet
Discharge = $2 \times 4.89 \times \sqrt{0.35} = 5.78$ cubic feet per second.

ADJUSTABLE SUBMERGED ORIFICE

A submerged orifice with a fixed opening is evidently unsuited to streams which are subject to wide fluctuations in discharge. For such conditions, a submerged orifice with an adjustable opening has been designed so that varying heads may be accommodated without endangering the banks of the canal. Such devices are in common use on many irrigation ditches.

The method of measurement for the determination of the difference in head is similar to that for the fixed orifice. In most cases the size of the opening can be adjusted by raising a gate which slides between guides nailed to the sides of the box. In such gates as this the size of the opening can easily be determined by calibrating the staff which raises the gate. A few measurements will determine how many square inches are added to the opening for each inch that the staff on the gate is raised. In many cases the adjustable gate is held in place by a bolt which slips through one of the holes on the staff of the gate and through the cross beam on the box. Since these holes are fixed, the hole through which the bolt passes is at once evidence as to the number of square inches in the opening. Labeling these holes with their respective openings does away with the necessity of repeated measurement. Figure 10 shows a gate arranged for this means of determining the size of the opening.

The additional strength necessary for this adjustable gate makes it necessary that an adjustable submerged orifice be built in a section of flume or a box in place of a single wall placed across the stream. Figure 10 is an isometric drawing of a submerged orifice placed in a flume and of a size sufficient for discharges varying from one half cubic foot per second to twenty cubic feet per second.

The accurate measurement of water through an adjustable submerged orifice can not be expected unless the individual structure has been rated in place. Conditions do not often permit the rating of orifices in the field. It has been found that variations in the structures, especially if built by carpenters with different degrees of skill, the cross section of the canal immediately above the structure, the velocity of the water as it approaches the structure, and the degree of submergence of the orifice itself may all affect the discharge through the orifice even if the area of the opening and the difference in head may be constant.

For these reasons a table of discharge for adjustable submerged orifices would have but little value because of the, at present, unavoidable error which would be introduced. The discharge can, however, be quite easily computed. Such computations are sufficiently accurate for most purposes.

Computation of discharge through adjustable submerged orifices.— The theory underlying the flow of water through adjustable orifices is the same as for fixed orifices. The same formulae apply:

$$Q = A\,V$$

$$V = C\sqrt{2gh}$$

Or

$$Q = A\,C \times \sqrt{2gh}$$

Or

$$Q = A\,C\,8.02\,\sqrt{h}$$

Where

Q = discharge in cubic feet per second
A = area of the orifice in square feet
V = velocity of the stream flowing through the orifice, in feet per second
C = a variable coefficient.
g = acceleration of gravity, 32.16 feet per second
h = difference in head in feet.

If the measurements of the area of the opening and the resulting difference in head are correctly made, the accuracy of the device depends upon selecting the proper value for the coefficient C for the existing conditions. Experiments conducted in the field laboratory at Davis, California, and in the hydraulic laboratory at Fort Collins, Colorado, suggest the use of the following values of C for various size of openings. If these values are used the per cent of error should be less than 6 per cent, unless other conditions in the individual structure are exceptionally bad.

Area of opening in square feet	*Value of C*
0.25 to 0.50	.80
0.50 to 1.95	.73
1.95 to 3.00	.68

These values of C can only be considered as trustworthy when the orifice is constructed according to the drawing (Fig. 10). Any change in the size of the posts or their location with respect to the flume would doubtlessly result in different side or bottom contractions. Other factors would then be introduced which would render these values of C unreliable.

The writer would be glad to correspond with water masters and irrigation managers in regard to the experiments mentioned above.

DESCRIPTION OF INCH BOX MEASUREMENT

A miner's inch is the amount of water which will flow through an opening one inch square when the center of that opening is held under a definite pressure. This required pressure varies in different localities. In most of the western states this pressure is fixed by the laws of the states.

In California, although the statute specifies a pressure of six inches above the center of the opening, a pressure of four inches is in universal use in the southern part of the state. In the newer fruit-growing areas of the Sierra Nevada foothills the statute pressure of six inches is in common use.

This definition of a miner's inch makes the measurement of water in this unit a simple matter. Many structures have been designed for such measurements. In these devices an adjustable opening is so placed that its center is exactly as many inches below a fixed overflow as the law or local custom prescribes. By regulating this adjustable opening the water above the opening can be backed up until the water surface stands at the exact level of the overflow. The average pressure on the opening is then that pressure which is required by the local custom, and each square inch in the opening delivers one miner's inch. The discharge through the opening in miner's inches can then be determined by measuring the opening and computing its area in square inches. The number of square inches in the opening is the number of miner's inches in the stream.

RIVERSIDE BOX

The device used on the Riverside Canal in southern California is shown in use in figure 11. The water enters through the bottom of the box and is measured out through an adjustable cast-iron measuring plate in the end. The opening of this plate is five inches high and by moving the iron slide gates it can be varied in width up to fourteen inches. The top of the plate is four inches above the center of the opening. This four-inch pressure conforms to the custom in

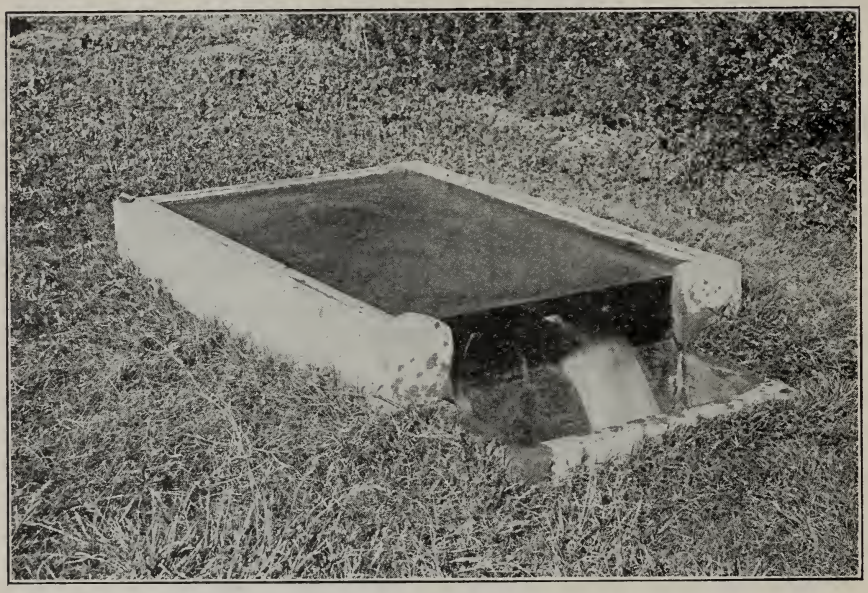

Fig. 11. Photograph of Riverside miner's inch box.

southern California. Thus, if the slides are set so as to hold the water surface at the top of the plate, the discharge in miner's inches will equal the area of the opening in square inches. Marks one inch apart are made on the plate to assist in measuring the width. When the water has passed through the plate, it is usually dropped into a concrete pipe line and led to the point of use. Care should be taken in planning the installation so that the water pouring through the plate will have a free fall into the basin below.

In cases where the Riverside box is used on pipe lines operating under considerable pressure it is often necessary that the measuring plate be installed in a standpipe several feet high. In such installations the water pouring through the plate drops into another

pipe high enough to provide the necessary pressure for the remainder of the line. The cost of installing a Riverside measuring plate in a concrete pipe line, in which the water is carried under pressure, varies so greatly that cost figures can not be given.

The Riverside box shown in figure 11 is designed for delivery of water into open ditches or into pipe lines which require no initial head. Such an installation would cost about $15.00. The plate alone sells for $2.50.

ANAHEIM UNION WATER COMPANY MEASURING BOX

The measuring box of the Anaheim Union Water Company is designed so that a definite amount of water can be diverted from the company's canal into the farmer's lateral or pipe line. The device consists of a by-pass into which water can be diverted from the main canal, an adjustable miner's inch plate, and an overflow crest, so set that any water diverted from the main in excess of the quantity required pours back into the company's ditch. The measuring plate is placed so that the center line of the adjustable opening is exactly four inches below the overflow. The inaccuracies of the device lie in the fact that the contractions* about the opening are very seldom complete. These inaccuracies are all in favor of the water user. Figure 12 shows the measuring box of the Anaheim Union Water Company in use.

* When a stream of flowing water passes over a weir having a crest length less than the width of the channel in which the water is flowing, the stream is said to have "end contractions." In such cases the actual width of the stream of water passing over the weir is slightly less than the width of the weir, this being due to the curvature of the water around the sides of the weir. Complete end contractions for any given weir opening are reached with a maximum curvature of the wall and therefore with the maximum decrease in the width of the stream. Through numerous experiments made by hydraulic engineers, the distance the sides of a weir must be from the sides of the channel in which it is placed in order to give complete contractions have been determined and with any distance less than this, the contractions would be "incomplete" and the quantity of water actually flowing over the weir will be somewhat different from that shown in the table for weirs with complete contractions. A weir with crest length equal to the width of the channel in which the weir is placed gives no end contraction or narrowing of the stream as it passes over the weir. Such a weir is known as a "suppressed" weir and different tables must be used with it. Such tables are not included in this circular because suppressed weirs are seldom used by farmers.

The term "complete contractions" is also sometimes used in connection with weirs to denote contractions on both sides and bottom; or in the case of an orifice, to denote contractions on all four sides.

SANTA ANA VALLEY IRRIGATION COMPANY'S MINER'S INCH BOX

A somewhat different type of inch box is used by the Santa Ana Valley Irrigation Company, in Orange County. This is merely a cemented section of the lateral in which the measuring board is placed. Water is forced into this cemented section of the lateral by stop gates placed across the main ditch. The farm lateral at the point of measurement is uniformly 33⅓ inches wide. The opening

Fig. 12. The Anaheim Union Water Company's miner's inch box.

is three inches high. If a stream of 100 miner's inches is desired, water is turned into the lateral until it stands four inches above the center of the opening in the measuring plate. If only fifty miner's inches are required, an opening one-half the width of the box is used. This opening is on one side of the lateral, however, instead of in the center, giving only one end contraction of the stream of water passing through. As a result of this, and also because there is no contraction on the bottom of the opening, the quantity measured does not correspond exactly with the amount measured through an opening of the same size, with contractions on all four sides.

THE AZUSA HYDRANT

It will be noted that the Riverside box described above can be used only for measuring the total flow in a ditch or pipe line. In

cases where the device must separate a certain flow from a larger stream some other method must be used. A common device of this sort is the Azusa hydrant. This hydrant is used exclusively on con-

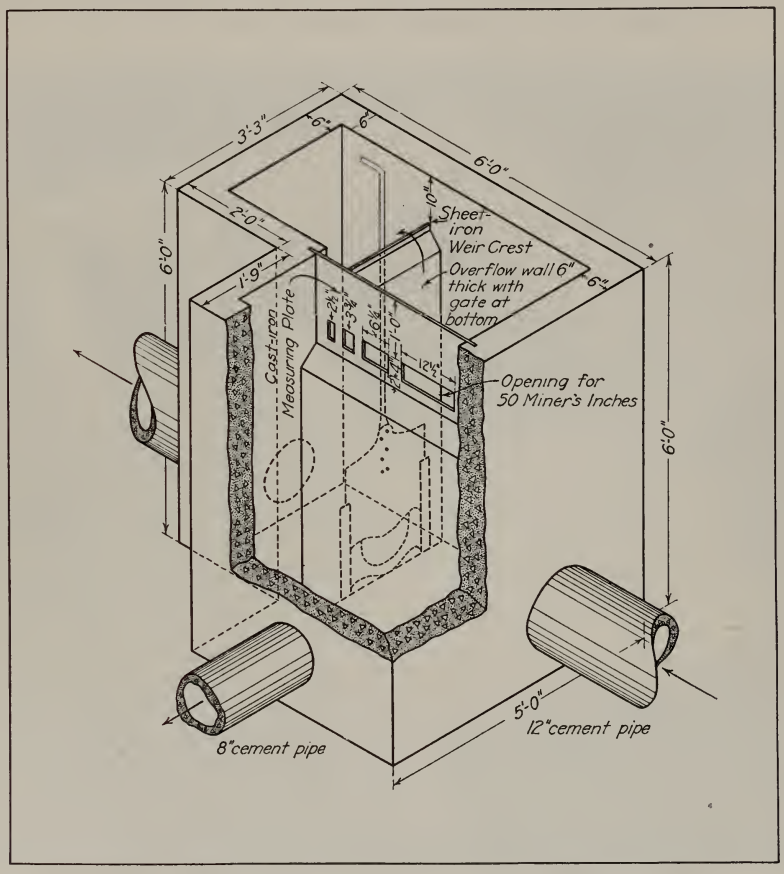

Fig. 13. Drawing of Azusa miner's inch box.

crete pipe lines and is usually used to separate from the water company's supply line the amount of water ordered by individual users.

This hydrant (Figs. 13 and 14) chiefly provides for measurement through one or more orifices on the center of which a pressure head of four inches is maintained by means of a sheet-iron spill crest set at right angles to the orifice plate. The hydrant is in the form of a concrete box placed over the supply pipe line. The openings in the orifice plate are four inches high and 2½, 3¾, 6¼, and 12½

inches wide, giving areas of 10, 15, 25, and 50 square inches, respectively. When the water surface on the upper side of these orifices is held four inches above their centers they will discharge, respectively, 10, 15, 25, and 50 inches. By using different combinations of these orifices several different amounts up to 100 inches can be measured. The water enters through the pipe shown in the drawing (Fig.

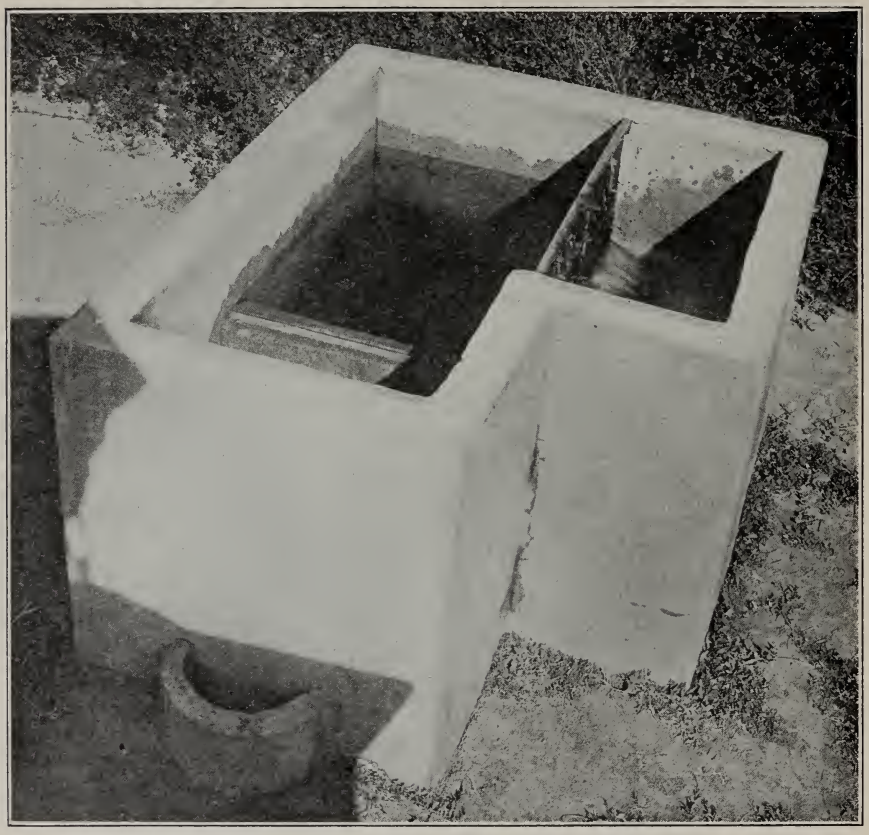

Fig. 14. Photograph of Azusa miner's inch box. Taken from above.

13). The orifices for the desired amounts to be turned out are opened and the others closed with slides. By adjusting the gate under the spillway the water can be brought to the crest of the spillway. If the water rises above the spillway a large part of the excess will be carried back to the supply line over the spillway, but any increase in depth on the orifices will also increase the amount turned out.

The Azusa hydrant as shown has walls six inches thick, all sides being vertical. The forms required in making it are therefore simple. The box contains 78.3 cubic feet of concrete. This can be made of

one part cement and four parts coarse sand. As the walls are six inches thick it is better to add some gravel (not larger than 1½ inches) to the sand where this can be obtained cheaply, but the proportion of one part cement to four parts of aggregate should be maintained. The concrete for this box including forms will cost from $18.00 to $20.00 under a large contract and about $30.00 if made singly. The plate with the openings and slides can be bought already made for $12.50 from foundries in the vicinity of the places the hydrant is used. The gate can be any of the usual types of slide gate.

The average of a number of tests made of this hydrant at Davis showed the amounts in inches being carried through the openings to be one per cent more than their area in square inches. This difference includes all errors in the measurements so that these openings are seen to be very accurate. The tests showed all openings or combinations of openings to be equally accurate. The box will therefore measure as accurately as is required. The openings are not as closely adjustable to the amounts turned out, however, as they are in the case of the box of the Riverside Water Company. Errors to be avoided in the use of this hydrant result from allowing the water to pass through the openings unevenly, which produces a swirling motion of the water as it rises to the openings; also from not so adjusting the gate under the spill-crest as to keep the flow over the spill to a thin film of water.

DIVISION BOXES

In some places in California, as well as in other western states, the waters in small streams are so allotted that an individual user is entitled to a definite proportion of the entire flow of that stream. This proportion is usually fixed by consideration of the number of irrigable acres each owner farms and the age of the established water rights. Canal companies in areas where this method of proportional delivery is common have at times adopted division boxes for the division and distribution of their supply. In such cases the company is commonly organized as a stock company and the stock purchased by the water users. One share of stock usually represents one acre of irrigable land. If, for instance, 100 shares of stock have been sold in a ditch company and one user owns ten shares, that user is entitled to 10/100 of the entire flow of the canal. Many types of division boxes have been designed in an effort to make this proportionate division just and accurate. All of these devices are based upon the principle that for a given head the discharge over two weir

crests set at the same elevation is approximately proportional to the length of those weir crests.

In the example given above the water user is entitled to 10/100 of all the water in the canal. Such a division might be made by setting two weirs at the same elevation in the canal near the farmer's turnout. If, for example, one of the weirs has a crest ten inches long and discharges its water into the farmer's lateral, and the other weir with a crest ninety inches long empties its water into the company's ditch, this proportionate division would be equitably accomplished, since the lengths of the weir crests would have the same ratio as that required by the conditions of the diversion. No matter how much water came down the canal, the user would receive 10/100 of the entire flow.

These division weirs are subject to the conditions already given for other weirs. These conditions are usually difficult to obtain throughout the length of a canal. The users at the upper end of the canal do not contribute toward the payment for water lost by seepage below them in the canal and the whole charge for this loss falls on the users at the lower end.

Several structures have been designed to obviate these difficulties, but in most cases this has been done at the sacrifice of accuracy in the division.

An isometric drawing of one of these devices is shown in figure 15. With this structure the water enters the flume at the left, is divided into the required proportion by the vertical cutwater, and is discharged into the user's flume which leads off to the right or runs out of the flume and into the company's ditch again. A flat crested weir set across both divisions of the flume and about three feet back from the entering end aids in the just division. In a structure of this sort the dividing partition in the flume is so set that its distance from the water user's side of the box holds the same proportion to the whole width as the number of shares of stock owned by the water user holds to the number of shares below him plus those he holds himself. In the case as given above the user owned ten shares of stock. One hundred shares had to be served by the water in the canal. The partition in his box would then be built so that it stood 10/100 of the way across the box. He, of course, would receive the water pouring through the narrower compartment. The hinged gate at the beginning of the user's flume will allow him to turn water into his ditch or back into the company's canal at will.

Such a structure assumes that water flows with an equal velocity at all points in a stream. This is never or very seldom the case, for the water near the banks is necessarily slowed down by weeds, rocks

or irregular earth work of the banks and bottom. With such a box the water user will usually receive less water than he is entitled to, for his share is taken from an area of reduced velocity while the water running past him comes from the fastest-flowing part of the stream.

A box such as that described above contains about 650 board feet of lumber.

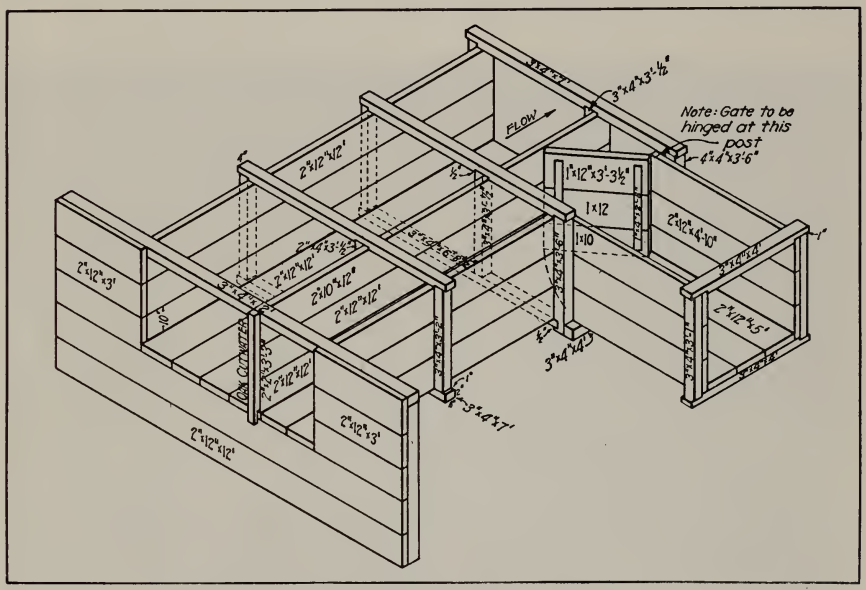

Fig. 15. Drawing of proportional division box.

MECHANICAL DEVICES FOR MEASURING WATER VOLUMETRICALLY

It frequently is desirable that a measuring device should record the volume of water delivered to irrigators, rather than the rate of flow. Numerous mechanically recording devices have been designed to accomplish this, several of these being described below. Without discussing the individual merits of these devices, it may be said that although several of them are in use in California and are believed by those using them to be giving more or less satisfactory service, there are many practical difficulties involved in operating devices of this nature. It would, therefore, seem that when a mechanical device is selected for measuring individual farmer's deliveries of irrigation water, the practical limitations of the device chosen should be understood. This is desirable in order that care may be taken to provide the conditions necessary for satisfactory measurements, and also that the need for occasional tests of the operating accuracy of the devices may be appreciated.

RELIANCE METER

The Reliance meter consists of a brass vane, shaped something like a propeller wheel, set in a throat, and a brass rod which connects the vane to the recording head. This recording head contains gearing which is connected with a counter. The figures in this counter show the number of acre-feet of water which have passed through the device.

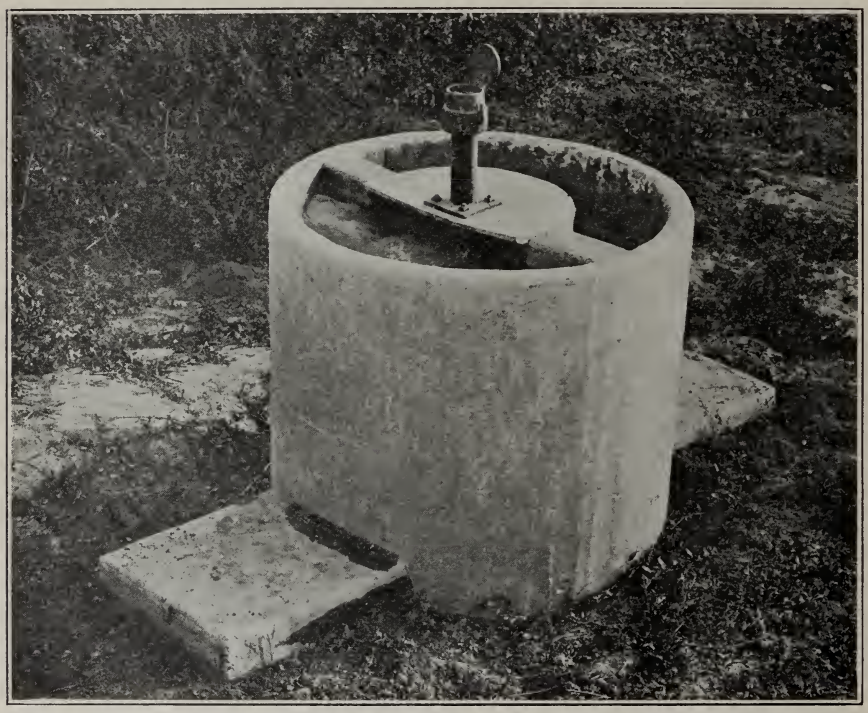

Fig. 16. Photograph of Reliance meter.

This apparatus is set so that the water to be measured pours between a series of plates or vanes and on to the propeller shaft in the throat. It can be used in either open ditches or concrete pipe lines.

The great advantage of such a device lies in the fact that it shows at a glance how many acre-feet of water have passed through the meter. With most other devices some computations are necessary to change the expression of the flow in cubic feet per second into terms of acre-feet.

Figure 16 is a photograph of a Reliance meter installed on a concrete pipe line.

DETHRIDGE METER

In the Reliance meter only a part of the stream hits the propeller wheel and turns it. In the Dethridge meter (Fig. 17) the whole flow of the stream is directed against the wheel. The wheel in this case is a large sheet-iron drum, three feet, four inches in diameter and two feet, six inches wide. Attached to the outer surface of this drum are a series of heavy blades which extend ten inches beyond the circumference of the drum.

Fig. 17. Photograph of Dethridge meter.

This drum turns in hardwood bearings attached to the concrete base. When the wheel turns the projecting blades fit closely into a depression in the concrete floor of the device.

Water, when turned into the device, presses successively against the blades on the cylinder and turns it in the bearings. A counter can easily be arranged to record these revolutions. With a Dethridge meter of the size described above, the discharge per revolution is about 30.5 cubic feet of water, regardless of the speed at which the wheel revolves. Each wheel installed should be accurately calibrated to determine the quantity of water discharged by the wheel per

revolution. The Dethridge meter has been very popular in Australia where a large number are in use. The device has never been used for the practical measurement of water in California. A description of the Dethridge meter is included in this circular because it involves a new principle.

OTHER MEASURING DEVICES

The Lyman meter. Many mechanical devices have been invented and patented by which the flow over weirs can be read as a quantity in terms of acre-feet, in place of as a rate of flow as in cubic feet per second. One of the more recent of these devices is the Lyman meter.

The Lyman meter consists of a small, delicately balanced brass turbine wheel, enclosed in a brass shell. This shell is attached to the down-stream face of a weir bulkhead and must be so set that a hole bored through the weir bulkhead and leading into the turbine shell shall have a fixed relation with the weir notch. On the up-stream side of the weir board is a brass tube in which carefully placed openings have been cut. This brass tube connects at its base with a short length of pipe which passes through the weir bulkhead and into the turbine shell.

The holes in the brass tube on the up-stream side of the weir bulkhead are of such varying diameters that they separate a certain definite proportion of the water from the stream going over the weir, no matter at what height the water may stand above the weir. This small flow passes down the tube, through the bulkhead and into the turbine shell, where it revolves the small turbine wheel. This wheel is geared to a counter in such a way that the quantity can be read directly on the face of the counter.

Different sizes of turbine wheels and different calibrations on the up-stream tube are necessary for use with weirs of various types and various lengths of crest.

The Sentinel meter. This meter is mounted in a 2-foot section of steel pipe designed to be set in an irrigation pipe line, the size of the meter and of the steel section depending on the size of such pipe line. A wheel or turbine set in the steel section turns as the water passes through the pipe line, the revolutions of the wheel being indicated by a counter set in a dial above the steel section, the gearing being so arranged that the quantity of water passing is directly indicated by the counter.

The Venturi meter. The Venturi meter is a device for the accurate measurement of relatively large flows of water. This device, in irrigation systems, is confined to large diversions from main canals into laterals and not to the measurement of water from the lateral to the individual user.

The *Venturi flume.* The Venturi flume is similar to the Venturi meter in theory. Water in an open ditch is led into a structure through a narrow throat and out into the original channel. In passing through this constricted cross-section, a difference in head above the device and in the throat always results. This difference in head, which may be determined as in the submerged orifice, is the measure of the amount of water which passes through the device. Tables and curves have been prepared to aid in determining the amount of water passing through the Venturi flume when the difference in water level above and below the device is known. The difference in head which results when a stream of water passes through the Venturi flume may be so small that it is very difficult to measure it accurately.

SUMMARY

Common devices for measuring irrigation water in California include rectangular, Cipolletti, and triangular weirs, submerged orifices with fixed and with adjustable openings, various miner's-inch boxes and hydrants, and numerous mechanical devices for registering the volume of water that passes through them.

In cases where the water to be measured is free from silt and where the grade of the ditch is sufficient to allow for the required backing up of the stream, some type of weir is undoubtedly the most satisfactory device.

A weir is accurate, cheap, easily installed and has no moving parts to get out of order. For small heads of water, a triangular or "V" notch weir is most accurate. For larger heads a rectangular weir is most satisfactory. A Cipolletti weir seems to have no advantage over a rectangular weir; it is harder to construct and for this reason is liable to be more inaccurate than the simple rectangular weir.

If the ditch grade at the required point of measurement is so flat that the necessary fall over a weir crest can not be provided, or if the water to be measured is so heavily charged with silt that a weir pond would rapidly fill up, a submerged orifice may be considered the most satisfactory device.

A submerged orifice of fixed dimensions, if carefully installed and with careful measurements for the difference in head, will give fairly accurate results. Accuracy is necessarily sacrificed when wide fluctuations in the stream to be measured make it necessary to install an adjustable orifice. With the adjustable orifice the coefficient "C," which is used in determining the discharge, varies with the area of the opening. Besides this indefinite value of "C" there is an added complication due to variation in individual boxes. The skill of the carpenter who builds the device may affect its discharge to a considerable extent under given conditions. At times an adjustable submerged orifice is the only device at all suited to the conditions which must be met.

Miner's inch boxes are used chiefly in the foothill orchard sections and in the citrus sections of southern California. These are usually installed by the company furnishing the water. If carefully installed and proper conditions of measurement are maintained, they will give approximately correct results.